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(71) Applicant(s):
FMC Technologies Inc
(Incorporated in USA - Delaware)
200 East Randolph Drive, Chicago,
Illinois 60601, United States of America

(72) Inventor(s):
Knut Thorvaldsen
Jøren Breda
Richard Kent
Steven Malone
Michael Tierney

(74) Agent and/or Address for Service:
Phillips & Leigh
5 Pemberton Row, LONDON, EC4A 3BA,
United Kingdom

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E21B 33/035

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US 5372199 A

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(54) Abstract Title: **Well completion system**

(57) A subsea wellhead completion system, which allows for independent retreival of a production string or a christmas tree, includes a tubing hanger 15 landed within a wellhead housing 10 and a tubing head adapter 30 landed within a tree housing 20 attached to the wellhead housing 10. The adapter 30 includes passages that provide an interface between passages 13 in the tubing hanger 15 and bores in the tree, having connection to external service lines. This makes it possible to use conventional tubing hangers with horizontal tree systems. In an alternative embodiement (fig 8, not shown); a tubing hanger upward extension interfaces with a lateral tree production port 23 and with annulus access and other service lines in the tree. The tubing hanger has a closure arrangement 18 to selectively seal the production bore. A removable cap 36 seals an upper end of the axial through bore.

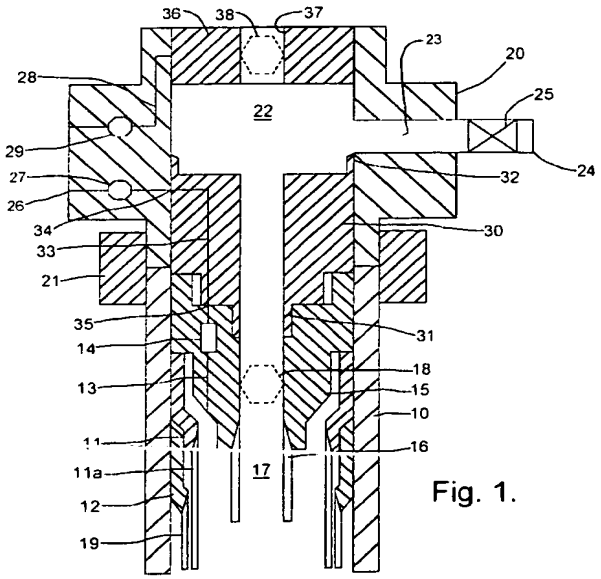

Fig. 1.

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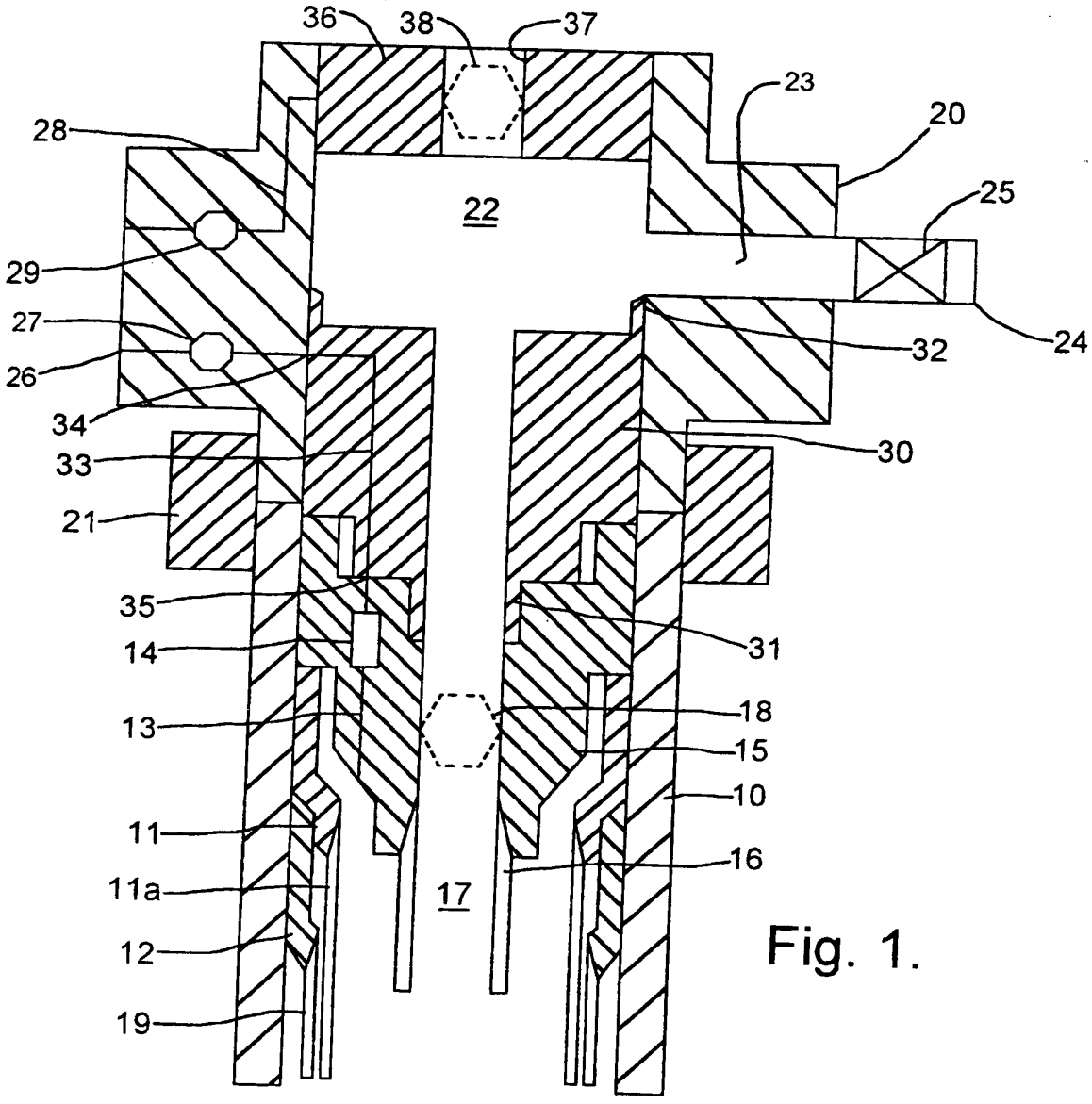
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Fig. 1.

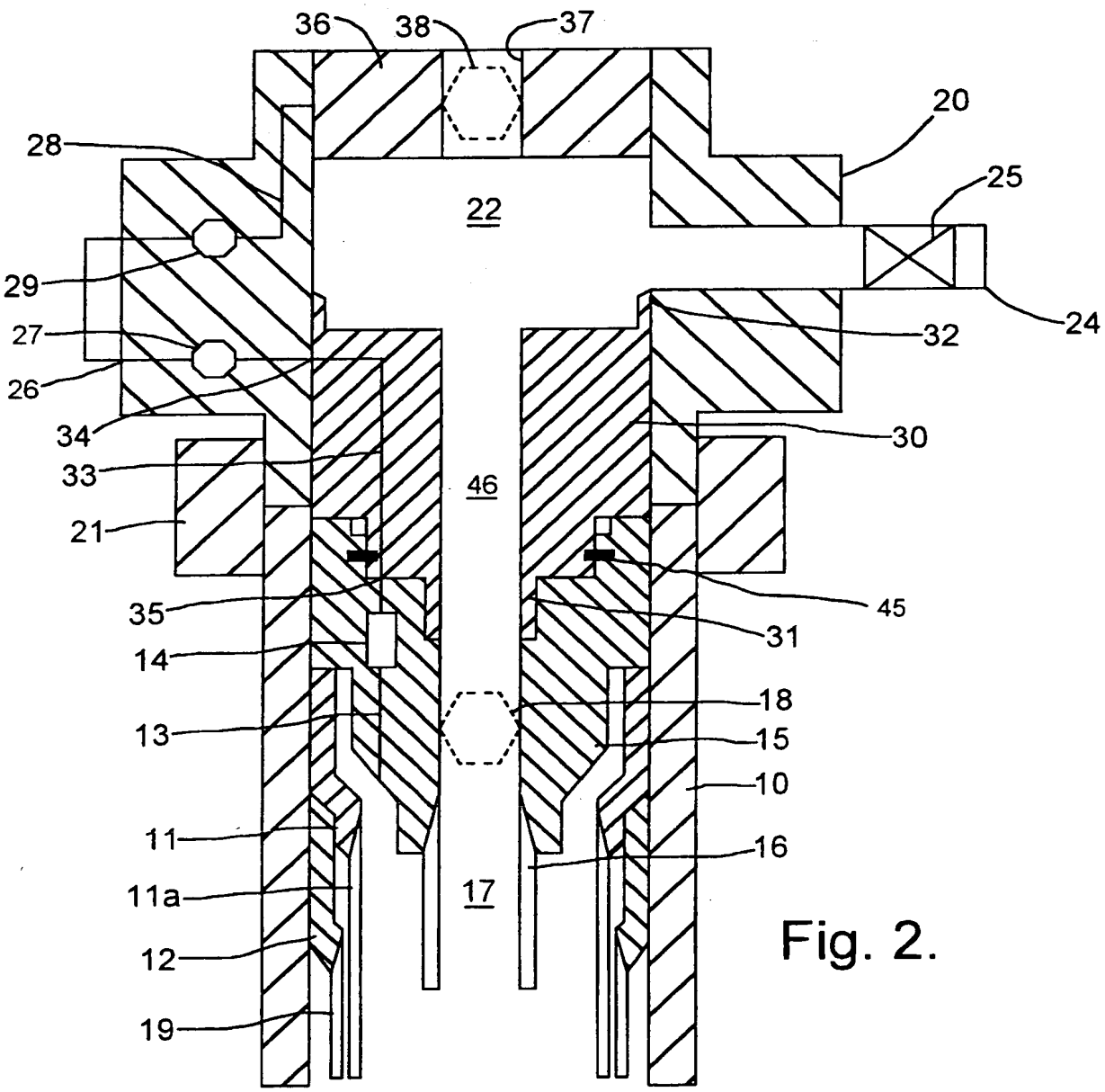
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Fig. 2.

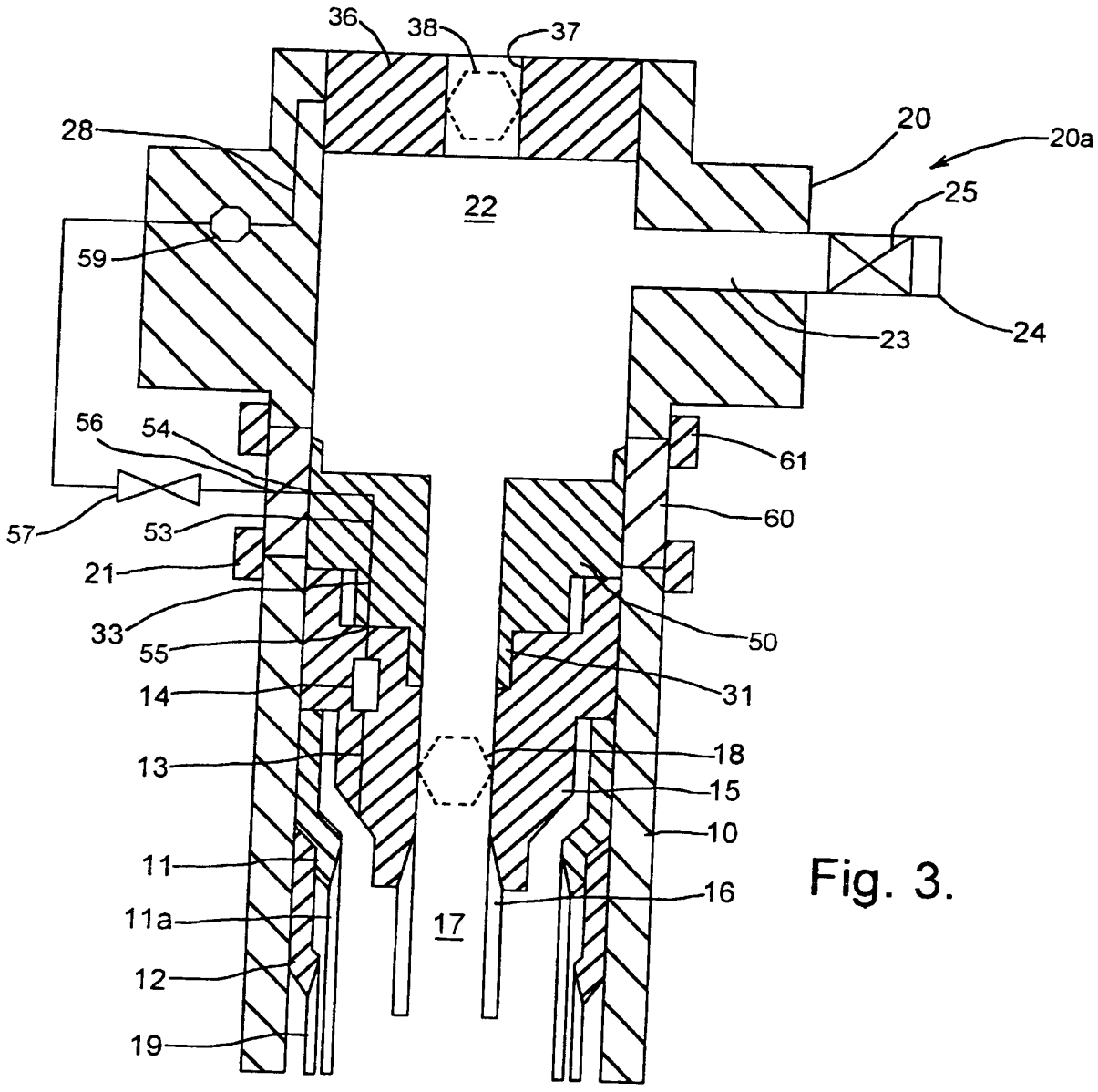
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Fig. 3.

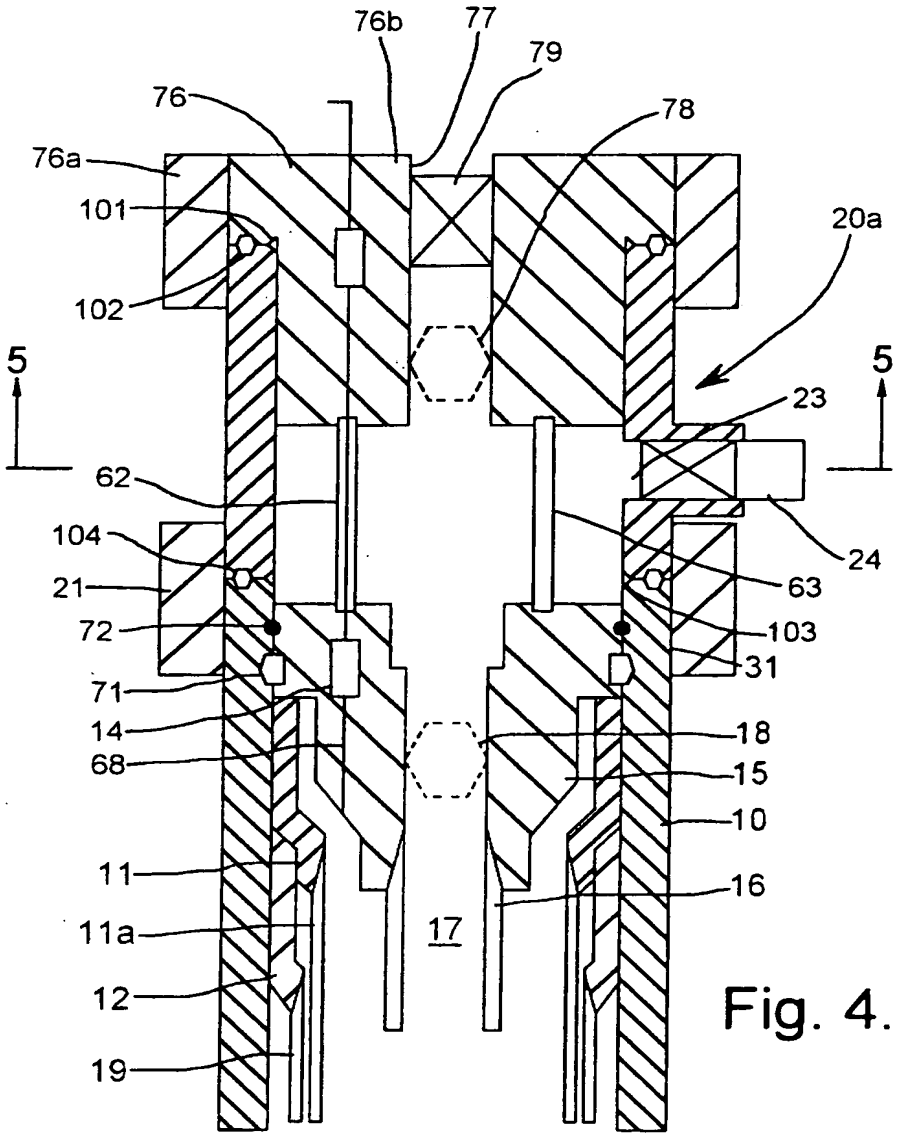
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Fig. 4.

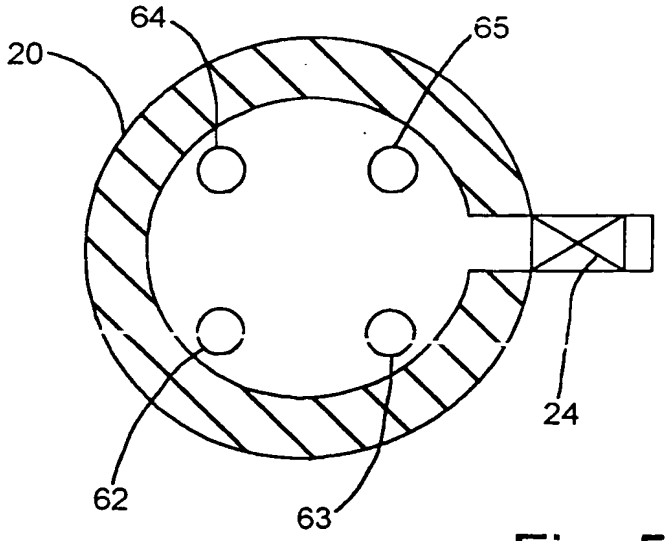
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Fig. 5.

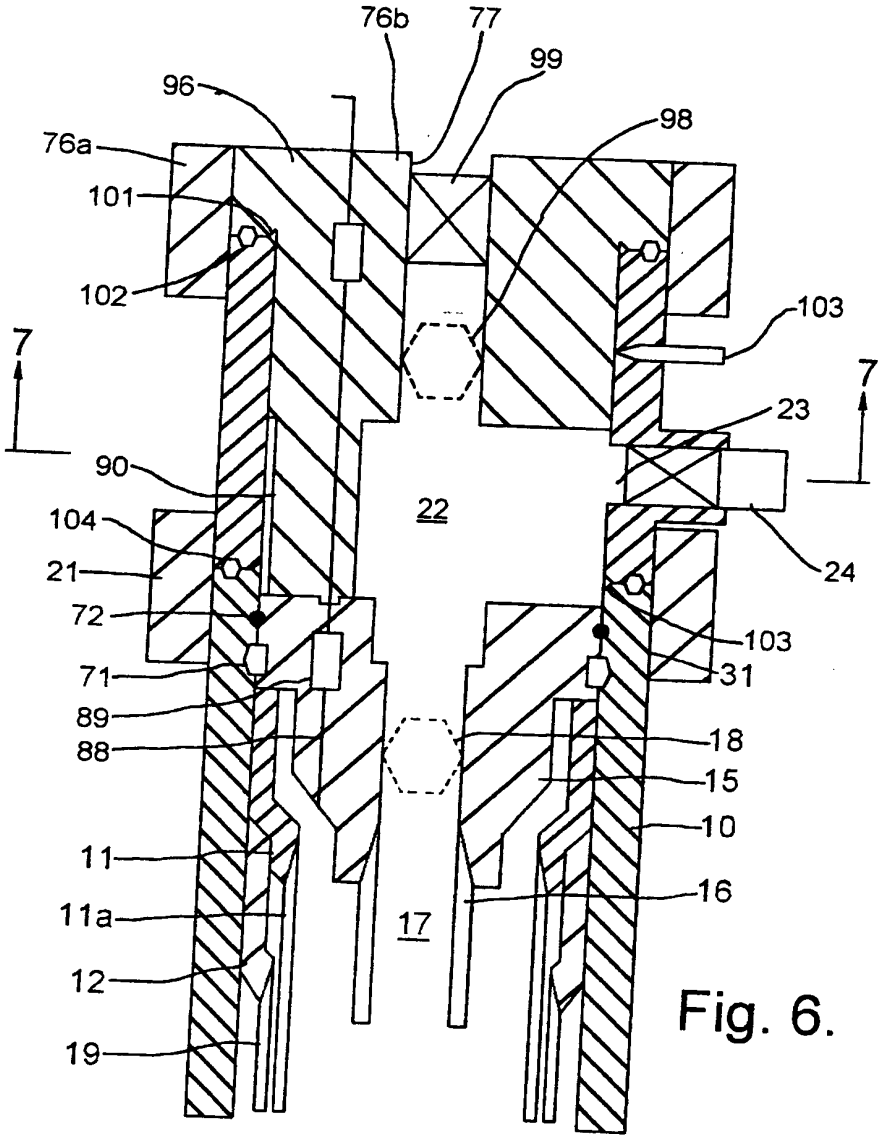
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Fig. 6.

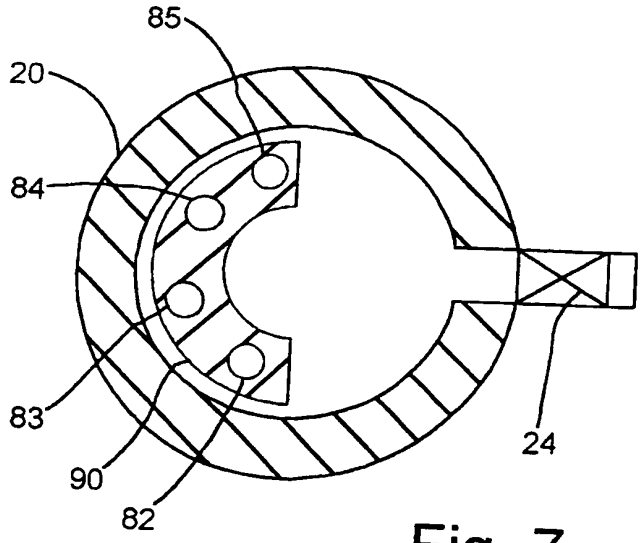
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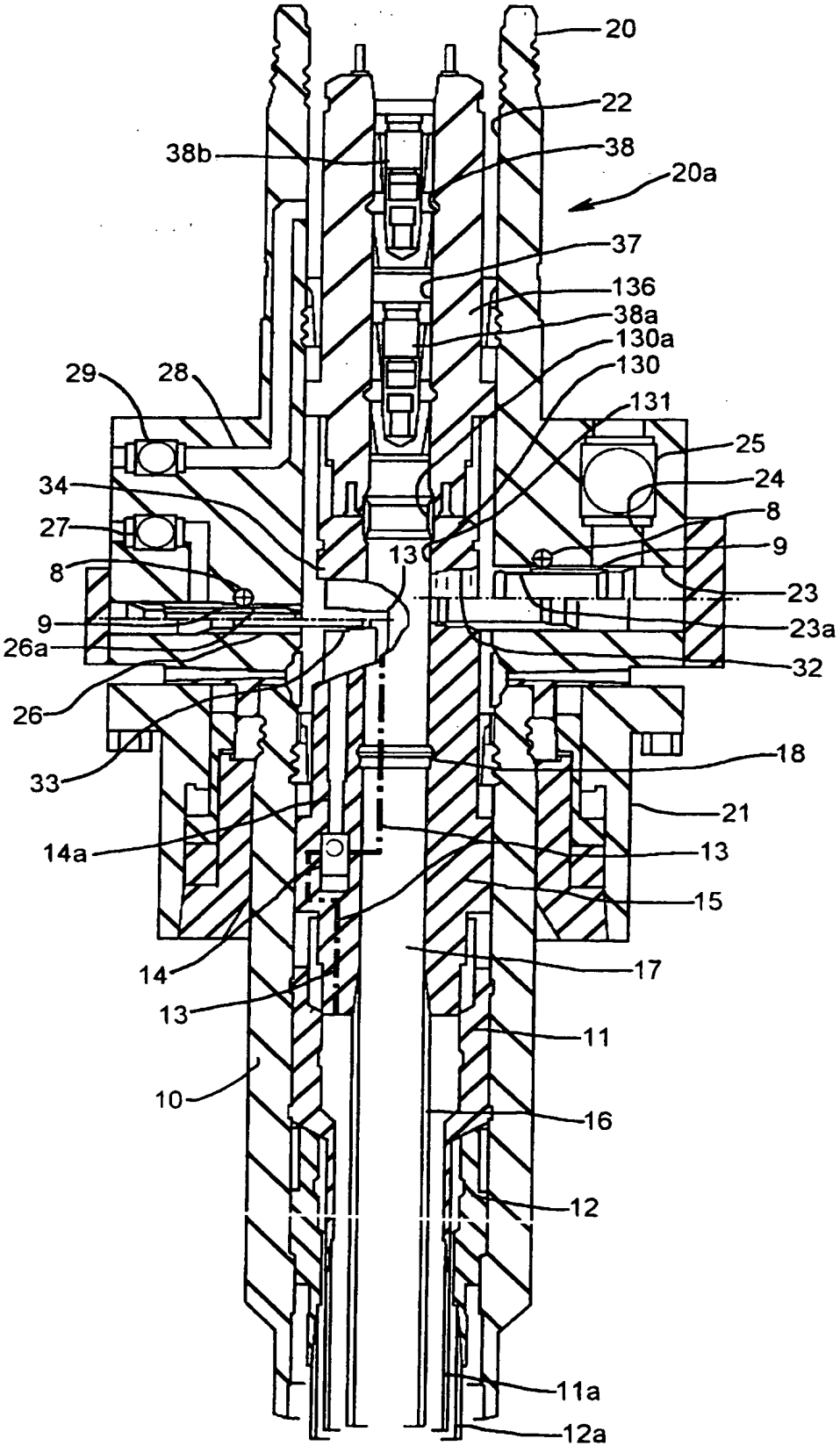
Fig. 7.

Fig. 8.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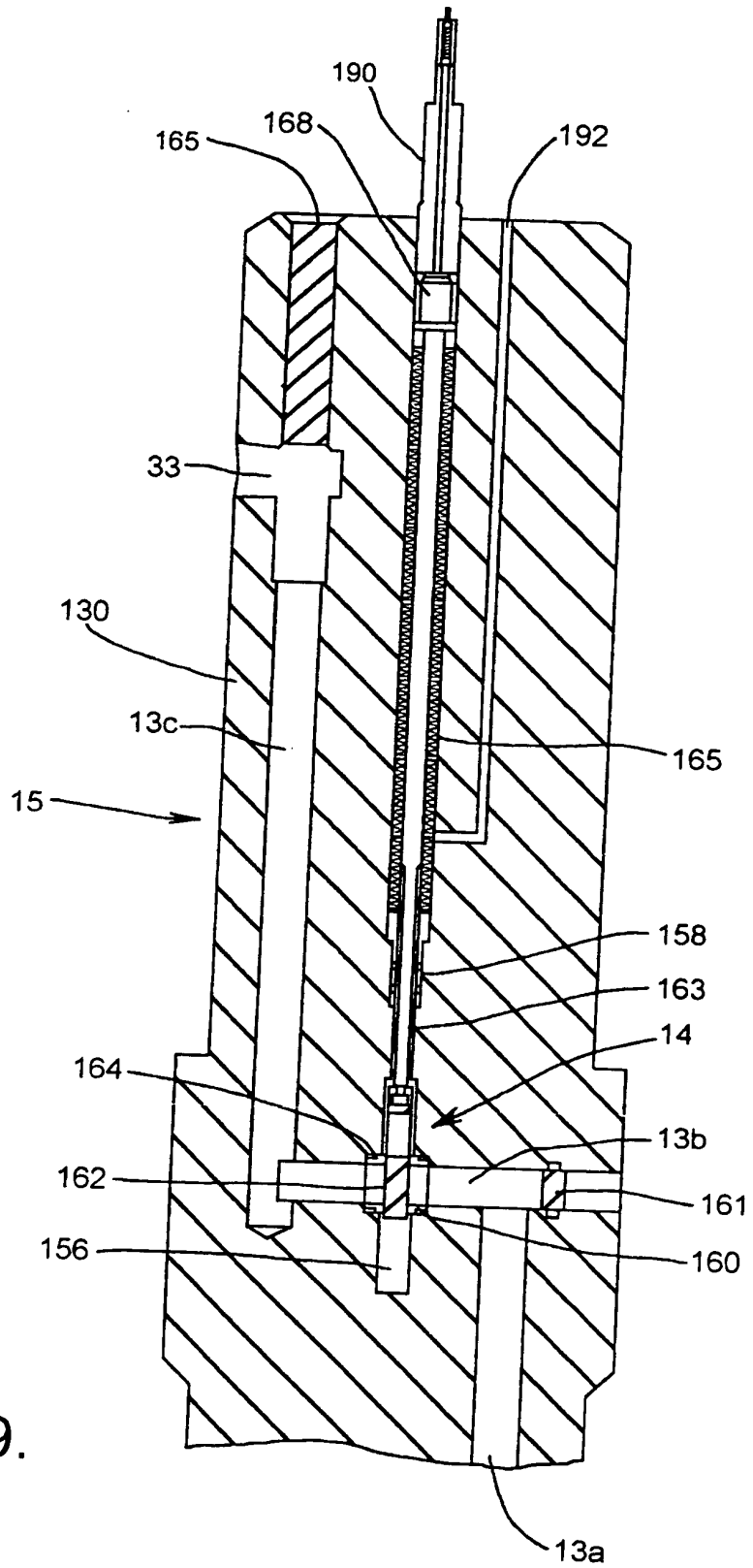
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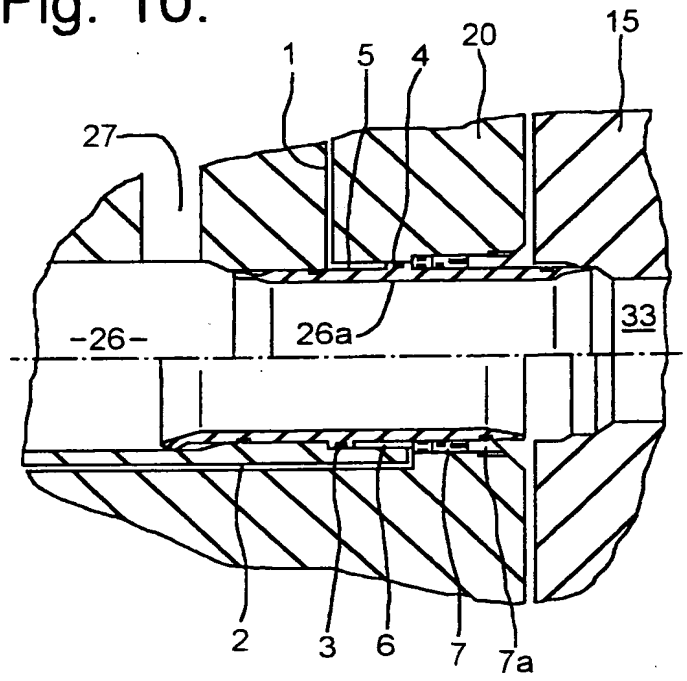
Fig. 9.

Fig. 10.



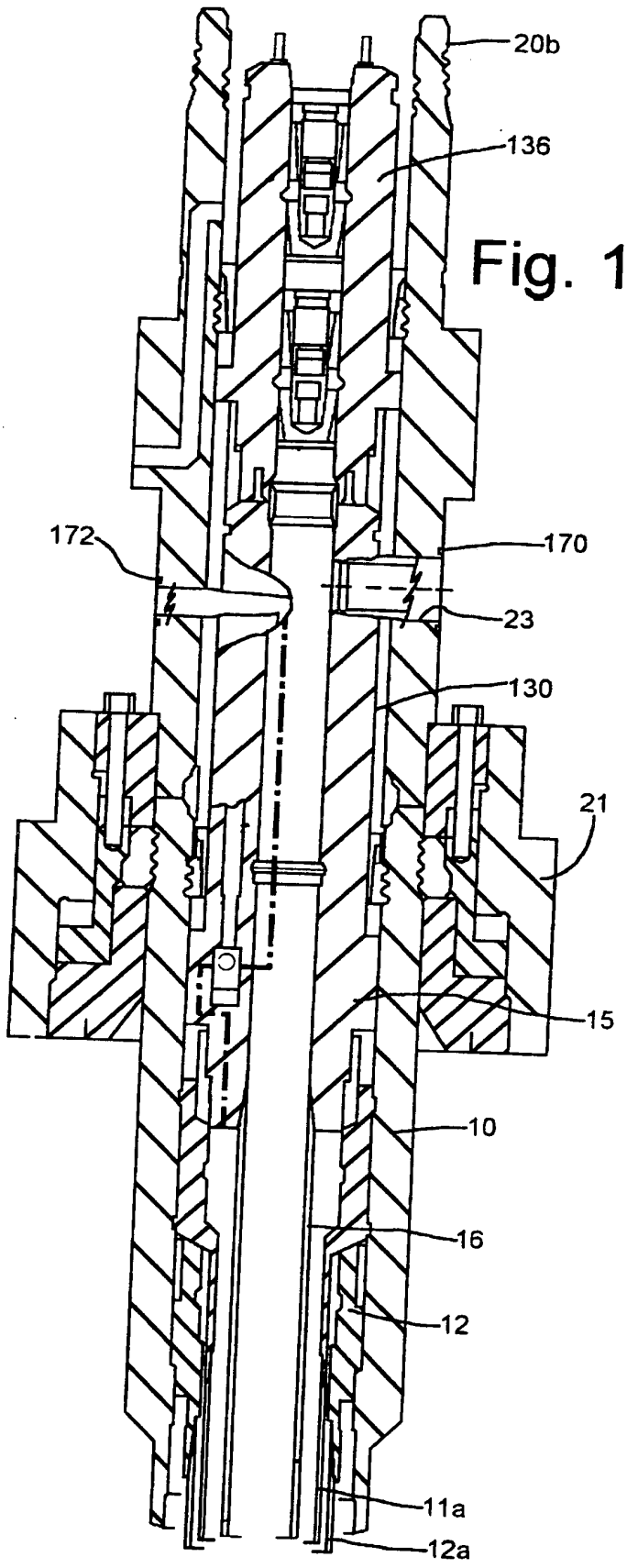


Fig. 11

WELL COMPLETION SYSTEM

Background of the Invention

The present invention relates generally to subsea wellhead systems. More specifically, the invention relates to a system providing an interface between a wellhead and a christmas tree such that the christmas tree may be removed from the well without removing the tubing. Such an arrangement is found in conventional subsea completions, but the present invention aims in addition to provide operational benefits found in horizontal completions. In preferred embodiments, the invention also makes it possible to use drill through techniques with less risk of damage to the tree.

A conventional subsea wellhead assembly includes a high pressure wellhead housing which supports one or more casing hangers located at upper ends of strings of casing extending into the well. A tubing hanger lands in the wellhead housing above or in the casing hanger and supports a string of production tubing that extends through the smallest diameter casing. An annulus bore may also extend through the tubing hanger, parallel to the tubing axis, for communicating the tubing annulus to above the tubing hanger. The annulus bore is needed during installation of the tubing hanger and tubing to establish circulation down the tubing and back up the annulus. After the well has been completed, the annulus bore is usually sealed, for example by a removable plug. Then a production tree is mounted to the wellhead housing. Access through the production tree to the tubing and/or tubing annulus may be necessary for various workover, monitoring or other operations during the life of the well.

With a conventional tree, the tubing completion is run in and landed and, before the BOP is removed, the production bore must be sealed e.g. with a wireline set plug. Then the tree is landed on the wellhead. The wellhead assembly requires at least one valve (usually a gate valve) for controlling flow of the production fluid from the production bore.

In recent years, operators have begun installing a different type of completion assembly, referred to generally as a horizontal tree. In a horizontal tree, the tubing hanger lands in the tree, not in the wellhead housing (nor in a tubing spool) located below the tree. The tubing hanger has a lateral flow passage extending from a through-going vertical passage. The

lateral flow passage registers with a lateral port extending through a sidewall of the tree. The tubing hanger and horizontal tree are provided within complementary guide means to rotate the tubing hanger and align its lateral flow passage with the lateral port in the horizontal tree. With a horizontal tree, the tubing hanger can be pulled (retrieved) from the tree without removing the tree.

With a horizontal tree, it is necessary to remove the blow out preventer (BOP) from the wellhead assembly to install the horizontal tree, and then replace the BOP on the horizontal tree before the tubing completion can be run. With the tubing completion installed, and before the BOP is removed from the tree, the vertical flow passage must be sealed above the lateral flow passage e.g. with a wireline set plug. In addition, for safety reasons, it is necessary to be able to isolate any potential production fluid flow from the horizontal tree's lateral port. Thus, in operation, the wellhead assembly requires at least one plug or similar closure member in the vertical flow passage of the tubing hanger above its lateral flow passage, and also requires at least one gate valve or similar flow control means for the production fluid in the tree lateral port.

For installation of the tubing hanger, a horizontal tree can have a comparatively large vertical bore without any in-line valves. Therefore the tree can be set at an early stage of the drilling of the well, so that a part of the drilling process is done with the tree in place.

In conventional as well as in horizontal trees, various production and annulus valves and chokes are mounted in or to the tree. These valves and chokes are not readily accessible from the surface. Some limited work can be performed on them with a remote operated vehicle (ROV). If a ROV cannot be used or the entire valve or choke needs to be replaced, it may be necessary to retrieve the tree. This is a time consuming and expensive task, particularly with a horizontal tree because the tubing must be pulled first.

US Patent no. 5,372,199 discloses an improved subsea wellhead with a horizontal Christmas tree in which either the production string may be removed, or the tree may be removed, each independent of the other. The structure includes a wellhead housing with casing hangers supporting casing strings landed in the housing. A lower tubing hanger is landed within the

innermost casing hanger in the wellhead housing similar to a conventional completion. Then, an upper false tubing hanger is landed within the tree, the false tubing hanger having communication with both the production line extending radially out of the tree and the tubing.

In this design it is possible to remove the tubing without first removing the tree or, if desired, remove the tree without removing the tubing, by first setting a plug in the lower tubing hanger and then removing the false tubing hanger.

This wellhead assembly can be completed by two methods. Firstly, with drilling and casing finished, the BOP can be installed on the wellhead housing, the tubing hanger run in through the BOP and landed within the wellhead housing, then the blow out preventer can be removed and the horizontal tree run and located on the top of the housing. Alternatively, after installing the wellhead with its surface casing, the horizontal tree can be located directly on the wellhead housing and a BOP installed on the horizontal tree. Further drilling and casing of the well can now be conducted through the horizontal tree and BOP. Then, the tubing hanger is run in through the BOP and horizontal tree and landed within the wellhead housing and the false tubing hanger is run in through the BOP, locating it above the tubing hanger with the lateral flow passage in the false tubing hanger aligned with the lateral bore in the horizontal tree. Lastly, the BOP is removed and the vertical through bore in the false tubing hanger is plugged above the lateral bore, and the or each valve opened to allow the production fluid to flow through the wellhead assembly.

The internal bore of the tree has several seal surfaces for the equipment needed to be landed and locked in the tree bore, such as the false tubing hanger and an internal tree cap. Using a completion method as described above, there is a significant danger of damaging these surfaces during drilling and costly protection sleeves are necessary. A further disadvantage with this structure is that extra seals are necessary as compared to a standard horizontal completion. Furthermore, separate trips may be necessary to retrieve and reinstall (i) the false tubing hanger and (ii) the lower tubing hanger with its tubing, when required.

Summary of the Invention

In a first aspect, the present invention provides a subsea wellhead completion system comprising:

a wellhead housing;

a christmas tree disposed above said wellhead housing and having an axial through bore;

connecting means for connecting said christmas tree to said wellhead housing;

said christmas tree including a first lateral production port for communicating said axial through bore with an external production line;

a tubing hanger installable in the wellhead through the axial through bore and having a production bore extending therethrough, said tubing hanger including a closure arrangement selectively operable to seal said production bore;

a removable cap which in use seals an upper end of the axial through bore so as to isolate a portion of the axial through bore and form a void in communication with the production port and the tubing hanger production bore. By sealing the tubing hanger production bore, the tree can be removed without removal of the tubing hanger. Alternatively, the tubing hanger can be pulled through the tree axial bore, without disturbing the tree or its fluid, electrical or other connections. The well fluids flow from the tubing into the void in the tree and from there to the production outlet.

The tubing hanger may have at least one service bore extending therethrough, said service bore communicating with the well below the tubing hanger, said tree and/or tree cap including at least one service port for communicating with an external service line; an adapter extending into said axial through bore and including at least one service passage extending therethrough, a lower end of said service passage communicating with said service bore and an upper end of said passage communicating with said service port. The adapter provides an interface between the tubing hanger and the tree. It is therefore possible to use any type of standard tubing hanger with any type of tree. It is therefore also possible to exchange a conventional tree with a horizontal tree, if so desired.

The tubing hanger and adapter can be locked together and run in and out as a single unit, thus saving a trip as compared to the prior art.

The invention is particularly suited to use with a standard type tubing hanger commonly used in so-called conventional completions, such as a concentric tubing hanger supporting a 7" or 9" tubing with the service bores grouped concentrically around the central tubing passage, or a dual completion type with a 5" x 2" tubing.

In a second aspect, the present invention provides a subsea wellhead completion system comprising:

a wellhead housing;

a christmas tree disposed above said wellhead housing and having an axial through bore;

connecting means for connecting said christmas tree to said wellhead housing;

said christmas tree including a first lateral production port for communicating said axial through bore with an external production line;

a tubing hanger installable in the wellhead and having a production bore extending therethrough, said tubing hanger including a closure arrangement selectively operable to seal said production bore;

a removable cap which in use seals an upper end of the axial through bore;

the tubing hanger and production bore extending into the tree in use, for communication with the lateral production port. Preferably the tubing hanger is installable in the wellhead through the axial through bore. This again allows the tree to be retrieved with the tubing hanger in place, or the tubing hanger to be removed without disturbing the tree.

Communication between the production bore in the tubing hanger and the lateral production port in the tree is preferably via a movable seal stab of the kind shown in UK published patent application no. 2,370,296. The stab is preferably extended into sealing contact with the production bore in the tubing hanger. It can be retracted when the hanger is not present, or to allow retrieval of the hanger. This makes the internal sealing surfaces of the tree less vulnerable to damage and a protection sleeve may not be necessary, even if the tree is in place during drilling operations.

The tubing hanger may have a vertical through bore, part of which forms part of the production bore, thereby providing vertical access to the tubing string when required.

The tree cap can be locked to the tree by using standard type external connectors with metallic seals. This avoids any seal surfaces within the bore of the tree whereby the tree can be made with only hardfaced internal surfaces such as by welding. The invention also removes the need for protective sleeves to protect the lateral bores of the tree during the drilling and casing process since there is no need to seal around the bore.

With the invention, the well can be completed, after installing the welhead and a surface casing, by locating the tree directly on the wellhead housing and installing a BOP on the tree. Further drilling and casing of the well can now be conducted through the tree and BOP. Then, the tubing hanger is run in through the BOP and tree and landed within the wellhead housing and a plug is located and secured in the tubing hanger through bore. The BOP can now be removed and the adapter (if used) is run in, locating it such that the flow passageways or electrical and other connections mate with corresponding passageways and connections in the tubing hanger or tree cap. Lastly, the plug in the tubing hanger is removed, for example through a bore in the tree cap, the tree cap bore containing a corresponding profile into which the plug is transferred to seal the cap. The or each production valve can then be opened to allow the production fluid to flow through the wellhead assembly.

Further preferred features and advantages of the invention are in the dependent claims and in the following description of illustrative embodiments made with reference to the drawings.

Brief Description of the Drawings

Figure 1 is a schematic illustration of the first embodiment of the invention.

Figure 2 is a schematic illustration of a first variant of Figure 1.

Figure 3 is a schematic illustration of a second variant of Figure 1.

Figure 4 is a schematic illustration of a second embodiment of the invention.

Figure 5 is a section taken along line 5-5 of Figure 4.

Figure 6 is a schematic illustration of a variant of Figure 4.

Figure 7 is a section along line 7-7 on Figure 7.

Figure 8 is a sectional view of a further embodiment of the invention.

Figure 9 is a sectional view through the tubing hanger with details of an annulus passageway and its closure device.

Figure 10 is a detail sectional view of a movable seal stab useful in certain embodiments of the invention.

Figure 11 shows a variant of the Figure 8 embodiment.

Description of the Preferred Embodiments

In Figure 1 is shown a wellhead of a standard type that includes a housing 10 having one or more (two as shown) casing hangers 11, 12 landed therein and supporting casing strings extending downwardly therefrom. A production tubing hanger 15 is landed in the wellhead housing 10 and supports a production tubing string 16 which extends downwardly therefrom. The tubing hanger has a production flow passage 17 extending therethrough in communication with the production tubing and a number of bores for service lines such as annulus access, electrical lines for use in communication with a downhole electrical device and hydraulic control lines. In Figure 1 only the annulus access bore 13 is shown extending through the tubing hanger for communication with the annulus between the tubing string 16 and the casing 11a. The annulus bore is preferably equipped with a closure device 14, such as a plug or a valve. If a valve is used, it may be hydraulically or mechanically operated. The tubing hanger also includes a prep. 18 for receiving a plug for closing the flow passage 17.

A Christmas tree includes a housing 20 and is suitably connected to the upper end of wellhead housing 10 by a remote operated connector 21. The tree has an internal bore 22 and a lateral production port 23. The lateral production port communicates with external production connection 24 which is under the control of a valve 25. A number of lateral ports extend through the wall of the tree. These are intended for communication and to provide outside access to the above mentioned service lines in the well, as will be explained below. For simplicity, only the annulus port 26 is shown in Figure 1. A valve 27 is installed in the annulus port, to control flow to/from the annulus, as will be described in more detail below. The annulus port may be connected to an outside crossover valve and/or to a second annulus bore 28 which extends through the tree to exit into the tree bore 22 above the lateral

production port 23. A second valve 29 may be installed in the second port to control flow of fluid therethrough. This enables annulus access in the usual manner.

An internal cap 36 is landed within the tree housing 20 and secured immediately above the production port 23. The internal cap includes an internal bore 37 with closure means 38, for example preps for one or more wireline set plugs, or a combination plug and valve, giving access to the internal bore of the tree without removing the cap 36.

A tubing head adapter 30 is landed and secured within the tree bore 22. The adapter includes a tubular member 31 threaded into its lower opening. Tubular member 31 extends downwardly and seals within the tubing hanger flow passage 17. The adapter includes a number of bores communicating with the service bores in the tubing hanger and the lateral service bores in the tree. In Figure 1 for simplicity only an annulus bore 33 is shown which has ports 34 and 35. Port 35 mates with the annulus access bore 13 in the tubing hanger and port 34 mates with the annulus port 26 in the tree sidewall. Although only the one bore is shown as an illustration it should be understood that the tubing head adapter may include electrical lines and connector(s) and hydraulic connector(s) for mating with the tubing hanger and tree in the same manner as described for the annulus bore.

Orienting means (for example a helical surface, not shown) on the adapter mates with an orienting member (for example an orienting pin, not shown) within the tree and causes the tubing head adapter to rotate so that the annulus port 35 registers with both tubing hanger annulus bore 13 and tree annulus bore 26. The tubing hanger 15 may also include a second orienting pin (not shown) pointing vertically upward to engage the lower end of tubing head adapter to ensure fine axial alignment of the entire assembly when it is installed on the wellhead or returned to the wellhead after having been removed. The tubing hanger running tool (not shown) may be provided with orientation means (for example an orientation helix for co-operation with a retractable pin in the BOP, not shown) for ensuring proper rotational alignment between the tubing hanger 15 and the tree housing 20. Such orienting means are well known and further description is unnecessary.

With this arrangement, the tubing hanger can be of a type which is best suited for the completion of the specific well, since the tubing head adapter can be configured for both the specific bore layout in the tubing hanger and the port design in the tree.

When ready for production, the internal cap 36 is secured and sealed within upper end of tree housing 20. The cap bore 37 is preferably located so that it registers with the axis of the tubular member 31 in the tubing head adapter and consequently with the tubing hanger flow passage 17. The cap bore 37 is provided with a plug prep 38 having a configuration corresponding to prep 18, allowing a single wireline retrievable plug to be seated and sealed either in cap bore 37 or tubing hanger flow passage 17. In production mode, the plug is seated in the cap bore prep 38. If the main flow passage 17 in the tubing hanger is offset from the wellhead axis, as in a dual completion, then the bore 37 is preferably also offset an identical distance.

When it is desired to recover the production tubing string 16, any suitable blowout preventer may be installed on the upper end of tree housing 20 to place the well under control and then cap 36 is released and recovered through the blowout preventer. With cap 36 removed a suitable tool is run to engage and recover tubing head adapter 30. Thereafter, a tool is run into engagement with tubing hanger 15, which has tubing string 16 suspended therefrom, and it is recovered from the wellhead housing 10 through the tree housing 20. With the production tubing and tubing hanger removed from the wellhead housing 10 any desired work or change in equipment may be performed in the well and then the production tubing and tubing hanger are again set in the wellhead housing 10 and the tree cap replaced to close the upper end of the tree bore 22.

In the event that it is desired that tree housing 20 be removed from the wellhead without removing the production tubing, a suitable blowout preventer is connected to the upper end of tree housing 20. With the blowout preventer in place, a wireline tool is run to release the plug from the cap bore prep 38 and re-seat it in prep 18 to close the production flow passage in the tubing hanger. The tree cap 26 can now be retrieved. Then tubing head adapter 30 with tubular member 31 and sleeve attached thereto, is engaged and retrieved. If necessary, a suitable wellhead seal cap can be secured on top of tubing hanger 15. This further seals the

production bore and annulus and/or protects the production and service bore connectors. With the well under control, the blowout preventer can be removed and then tree housing 20 is removed. After all operations planned for the well while the tree -is removed, tree housing 20 is returned and connected to the upper end of wellhead housing 10 and the blowout preventer connected to the upper end of tree 20. The remainder of the production equipment including tubing head adapter 30 and tree cap 36 is reinstalled and lastly the tubing hanger plug is removed from prep 18 and reinstalled in prep 38.

In the event that both the tree and the production tubing string 16 are to be retrieved, then its is suggested that the tubing string 16 should be recovered as set forth above and a suitable plug is set in the inner casing hanger to close the well and thereafter, the tree can be released and retrieved by remotely releasing clamp 21 and recovering them to the surface.

In Figure 2 there is shown a first variant of the embodiment shown in Figure 1. The tubing head adapter 40, instead of being locked in the tree bore 22, is releasably connected to the tubing hanger. The connection can be of any type, for example mechanical locking dogs (45 as shown) or an hydraulic type locking means. Another possibility is to use shear pins that break on an upward pull. However, in the latter case the tool for setting and pulling the tubing hanger must lock into the tubing hanger.

In the event that it is desired to pull the tubing 16 from the well, a suitable tool is latched to the adapter 40 to pull both the adapter 40 and the tubing 16 in one operation. If it becomes necessary to pull the tree, then the connection between the adapter and the tubing hanger can be broken so that the adapter can be retrieved to the surface alone.

In Figure 3 is shown another variant of the embodiment shown in Figure 1. As shown the tubing head adapter 50 is oriented and secured in a tree sub 60 which is disposed between wellhead 10 and tree housing 20 with connectors 21 and 61 respectively. The sub 60 contains all ports, stabs, penetrators, couplers etc. for registering with the ports etc. in the tubing head adapter. When the tubing head adapter 50 is properly oriented, the passages and lines in the tubing hanger (annulus, hydraulic, electrical, etc.) register with the ports, stabs, etc. in the sub 60. As an example there is shown tubing head adapter annulus bore 53 with a

lower port 55 communicating with tubing hanger annulus bore 13 and upper port 54 communicating with conduit 56 in sub 60. Conduit 56 may contain valves or other closure means 57, 59.

This arrangement has the advantage that no modifications are needed to the tree so that a standard type large bore tree 20a can be used. Any passages in the tree which in this case are not used can simply be plugged up.

An advantage with the system as described is that, with suitable precautions, the tree can be mounted at an early stage and the deeper part of the well drilled with the tree in place. Another advantage with the invention is that during workover operations, any debris that falls down into the tree from the riser, e.g. during running of the tree cap, will simply fall down on top of the adapter and be flushed out with the production fluid.

In Figures 4 and 5 there is shown a second embodiment of the invention. The tubing hanger 15 is again landed within the wellhead housing 10 and supports a production tubing string 16 which extends downwardly therefrom in the same manner as described with reference to Figure 1. The tubing hanger also includes the bores e.g. 68 for the usual annulus and service lines as explained above. Tubing hanger lockdown means 71 and sealing ring 72 are schematically indicated. The tree 20a includes a lateral port 23 with production valve 24.

A combination external/internal tree cap 76 is landed on the tree 20a extending into the tree bore 22 above the production port 23. A cap inner portion 76b is locked and sealed to the tree using a connector portion 76a with metal seals 101, 102 that will provide a barrier between the production and the outside. The metal seals are preferably identical to those 103, 104 used between the wellhead housing and the tree and connector 76a is of relatively standard type similar to the wellhead connector 21 used. The tree cap includes a central bore 77 preferably axially aligned with the tubing hanger passage 17. The central bore includes means for installing closing means, for example as shown a plug 78 and a valve 79 for closing off the bore 77 when the well is in production, while giving access to the internal bore of the tree, for example for placing the plug 78 in or retrieving it from the tubing hanger prep. 18 or the corresponding prep. in the tree cap bore 77 below the valve 79. Alternatively,

separate and/or different plugs can be used in the bores 17, 77. Concentrically arranged around the central bore 77 are bores for service lines. These smaller bores extend through the cap, between ports with sockets on the underside and connections on the topside of the cap. In the bores can also be installed valves or, in the case of wanting to close the bore altogether, plugs.

From the underside of the cap there extend a number of tubular members, four, 62, 63, 64, 65, as shown in Figure 4. These can be pipes screwed into the sockets on the underside of the cap. The lower end of each member mates into a socket of the corresponding type bore in the tubing hanger. The tubular extension can house electrical lines or form passages for fluid between the well below the tubing hanger and an external line. In Figure 4, as an example, tubular member 62 houses the annulus access bore and connects with the lower annulus bore 68 in the tubing hanger.

Because the service lines extend right through the cap, no bores are needed in the tree, except the production port. Also, since there are no seal surfaces inside the tree bore, and in general less need for fine tolerances in manufacturing, this assembly is particularly suited to drill through practices, i.e. carrying out drilling operations through the tree.

The well is completed by installing the tree 20a on the wellhead housing 10 after drilling the hole for and setting surface casing. The tree and wellhead can be made up at the surface location and run together into the well with the surface casing, if so desired. A BOP (not shown) is connected to the tree and further drilling and casing of the well is conducted through the tree and BOP. After drilling, the tubing hanger 15 is run in through the BOP and tree and landed within the wellhead housing 10. A plug such as 78 is set in the tubing hanger production passage prep 18 to isolate the well and the BOP can be removed. Next, the tree cap 76 is run, landed and locked to the tree 20a with its downwardly extending members 62, 63, 64, 65, within the tree. When properly oriented, each of the extension members will mate with its corresponding receiving socket in the tubing hanger. When the tubing hanger is opened for production, by removing the plug 78 and for example installing it in the tree cap bore prep below the valve 79 as shown, the production fluids will flow between and around the tubular extensions and into the lateral port 23.

If it becomes necessary to recover the production tubing string 16, the well is shut down, the plug 78 is moved to the tubing hanger prep 18, the upper connector 76a is released and the cap 76 removed to the surface. Then a blowout preventer is installed on the upper end of the tree 20a and a suitable tool is run to engage and recover tubing hanger 15 with tubing string 16. With the production tubing and tubing hangers removed from the wellhead housing 10 any desired work or change in equipment may be performed in the well and then the production tubing and tubing hangers are again set in the wellhead housing 10. Each other fluid passageway through the tubing hanger, including the annulus passageway 68, is closed by a valve such as 14, or a self-closing coupler or the like, which produces a fluid-tight seal when the extending members 62, 63, 64, 65 are withdrawn from the tubing hanger 15. Suitable coupler closure devices are described in WO01/81801.

Similarly, if it is desired to remove the tree without removing the production tubing, a tool is run through the central bore 77 of the cap to move the plug 78 from the bore 77 to the tubing hanger prep. 18. The well is now under control and the tree 20a can be removed. After all operations planned for the well while tree 20a is removed, tree 20a is returned and connected to the upper end of wellhead 10 and the plug 78is removed from prep 18 and re-seated in its prep. in the tree cap 76.

In Figures 6 and 7 there is shown a modified version of the invention of Figure 4. The service lines are located within housing 90. The housing 90 can either fixed to the underside of the cap 96 or machined as one piece with the cap. The housing preferably has a half moon cross-sectional shape as shown (Figure 7) with an outer curve that fits within inside tree bore 22. The housing can end in a circular ring with members for stabbing into the tubing hanger sockets or the tubing hanger can be modified so that its receiving sockets are arranged in a similar half-moon configuration. In Figure 7 there are shown only four service lines, 82, 83, 84, 85. In the case that there are more needed than can be accommodated within the housing 90, two such housings can be included. The tubing hanger and the tree must in that case be oriented so that none of the housings will obscure the production port 23 when installed. Orienting means (for example a helical surface, not shown) on the portion of the tree cap extending into the tree bore 22 mates with an orienting member (for example an orienting

pin, 103) on the tree and causes the tree cap 96 to rotate so as to achieve proper rotational alignment with the tubing hanger 15 and port 23. Conventional techniques can be used to orientate the tubing hager 15 relative to the tree 20a. Similar orientation techniques can be applied to the tree cap 76 and tubing hanger 15 shown in Figure 4.

Figure 8 shows an embodiment of the invention in its second aspect. A wellhead includes a housing 10 in which casing strings 11a, 12a are supported on casing hangers 11, 12. A tubing hanger 15 is landed in the wellhead housing 10 and supports a tubing string 16 in the well. The tubing hanger has a production bore 17 extending therethrough and into the tubing. A number of passages for service lines such as annulus access, electrical lines for downhole electrical devices and hydraulic control lines also extend through the tubing hanger. In Figure 8, as an example of such a service passage, an annulus access passage 13 is shown schematically in chain dotted lines in communication with the annulus between the tubing string 16 and the casing 11a. Although Figure 8 apparently shows the production bore 17 superimposed on the annulus passage 13, this is illusory, arising as a consequence of the viewing direction. In fact the annulus passage 13 extends through the wall of the tubing hanger in isolation from the production bore 17. The annulus passage 13 may be equipped with a closure device 14, such as a plug, or a gate valve as shown. If a valve is used, it may be hydraulically or mechanically operated, e.g. by actuator stem 14a. Suitable gate valves are described in WO01/73256. The tubing hanger 15 also includes a prep. 18 for receiving a closure member such as a plug or valve (not shown), for closing the flow passage 17. Alternatively, this prep may be lower down in the production tubing string 16.

A Christmas tree 20a includes a housing 20 and is suitably connected to the upper end of wellhead housing 10 e.g. by an hydraulic connector 21. The tree has a vertical through bore 22, communicating with a lateral production port 23. An internal cap 136 is landed and secured within the tree 20a above the lateral production port 23. The internal cap includes an internal bore 37 with closure means 38, for example preps for one or more wireline set plugs, 38a, 38b or a combination plug and valve, giving access to a vertical through bore 131 in the tubing hanger 15 without removing the cap 136.

The tubing hanger includes a portion 130 which extends to a point above the tree's lateral production port 23. The portion 130 forms an integral structural part of the tubing hanger. The completion production bore 17 extends through the tubing hanger and comprises a lateral flow passage 32 axially aligned with the lateral production port 23 in tree 20a.

Orienting means (not shown) on the tubing hanger mate with an orienting member (not shown) within the tree to cause the tubing hanger to rotate so that its lateral flow passage 32 and a laterally extending annulus port 33 at the upper end of the annulus access passage 13 register with the lateral production port 23 and an annulus port 26 in the tree respectively.

The lateral production port 23 communicates with external production connection 24 which contains a valve 25. A number of lateral ports extend through the wall of the tree. These are intended for communication with and to provide outside access to the above mentioned service lines in the well, as will be explained below. For simplicity, only the annulus port 26 is shown in Figure 8. A valve 27 is installed in the annulus port, to control flow to/from the annulus, as will be described in more detail below. The annulus port may be connected to an outside crossover valve and/or to a second annulus port 28 which extends through the tree to exit into the tree bore 22 above the tubing hanger 15. A second valve 29 may be installed in the second port to control flow of fluid therethrough. This enables annulus access in the usual manner.

The internal cap 136 stabs into the upper end 130 of the tubing hanger 15 and seals within vertical through bore 131 by a seal stab 130a. The cap bore 37 is preferably located so that it registers with the axis of the through bore 131 in the tubing hanger and consequently the production string 16, and preferably has a configuration to allow a lower plug (not shown) to be seated and sealed within the production bore 17 of the tubing hanger in prep 18. If the vertical through bore 131 and production bore 17 in the tubing hanger are offset from the wellhead axis, as in a dual completion, then the cap bore 37 is preferably correspondingly offset.

The tubing hanger extension 130 can have an outer diameter designed as a sliding fit within the tree bore 22 and have seals (not shown) located above and below the lateral port 23 in the

tree. However, in the preferred embodiment the tubing hanger extension 130 has an outer diameter smaller than the lower part of the tubing hanger 15 and consequently smaller than tree bore 22. A radially movable stab 23a is located in the tree lateral production port 23 and can be made to extend into the tree bore 22 to stab into and seal with tubing hanger lateral flow passage 32 when the two are in axial alignment. Likewise, a radial hydraulic stab 26a is located in the tree annulus port 26 and can be made to extend and stab into and seal with tubing hanger lateral annulus port 33 at the upper end of the annulus access passage 13 when the two are in axial alignment. A broken away section on the left hand side of Figure 8 shows the interface between the tubing hanger lateral annulus port 33 and the seal stab 26a. The upper half of this section shows the stab 26a retracted clear of the tubing hanger extension 130 and the lower section half shows the stab 26a extended into sealed fluid communication with the annulus port 33 in the tubing hanger extension 130. Similarly, the upper half of the section on the right hand side of Figure 8 shows the production seal stab 23a retracted clear of the tubing hanger extension 130 and the section lower half shows the stab 23a extended into sealed fluid communication with the lateral flow passage 32. A suitable type of radial stab is shown in applicants' UK specification no. 2,370,296.

The tubing hanger annulus passage 13 and closure device 14 are shown in more detail in Figure 9. The annulus passage 13 comprises lower, axially extending portion 13a whose lower end communicates with the tubing annulus (not shown), a transversely extending portion 13b, and an upper, axially extending portion 13c whose upper end is in communication with the tubing hanger annulus port 33. The passage portions 13b, 13c are formed by drilling into the hanger body and inserting plugs 161, 165. A valve gate 162 is movable transversely of the passage portion 13b to selectively block or allow fluid flow through it. Co-operating valve seats 160, 164 are provided on either side of the gate 162. Hydraulic pressure applied to the upper surface of a piston 168 through a male coupler 190 moves a gate actuator stem 163 downwardly against the bias of a belleville washer stack 165. Stem 163 is sealed within the body of the tubing hanger 15 by a packing 158, to isolate a valve chamber 156. If necessary, the piston 168 and stem 163 can be moved in the opposite direction by hydraulic pressure applied via line 192. The belleville washer stack makes the gate 162 fail safe closing.

The other sevice lines through the tubing hanger interface with similar coupling means in the tree, for example electrical or fluid penetrators. The fluid couplings used either in the tree or tubing hanger or both may be of the self-sealing type, for example as described in WO01/81801.

As shown in Figure 8, the seal stabs 23a, 26a are moved by pinions 8 and racks 9. The pinions 8 are mounted on shafts (not shown), rotated by electric or hydraulic motors/rotary actuators. These may be situated on the outside of the tree 20a, with the shafts extending through suitable rotary seals. Figure 10 shows a seal stab 26a which is directly hydraulically actuated. A circumferential piston 4 extends outwardly from a centre section of the stab 26a and is a sliding fit in a counterbore formed in the annulus port 26. The piston is sealed to the counterbore by a sealing ring 3 so as to define a pair of closed hydraulic chambers 5, 6 on opposite sides of the piston. The chamber 5 is closed by a U-profile metal-to-metal seal ring 7 and a backup/energizing nut 7a. The seal stab 26a is retracted by supplying hydraulic fluid through a line 2 to chamber 6 (see lower half of Figure 9) and extended by supplying hydraulic fluid to the chamber 5 through a line 1.

An advantage with the system as described is that, with suitable precautions, the tree can be mounted at an early stage and the deeper part of the well drilled with the tree in place. Another advantage with the invention is that during workover operations, any debris that falls down into the tree from the riser will simply fall down on top of the adapter (if present) or tree through bore and be flushed out with the production fluid.

Figure 11 is similar to Figure 8, except that the seal stabs 23a, 26a, and valves such as 25, 27, 29 are contained in separate blocks (not shown) releasably connected (e.g. bolted) to the tree body 20b. Backup seals 170, 172 are provided in series with the production and annulus seal stabs. These blocks may therefore be installed and retrieved independently of the tree body 20b. The seal stabs may be actuated as shown in Figures 8 and/or 10.

From the foregoing, it can be seen that the present invention provides an improved subsea wellhead in which either the production equipment within the well may be safely and quickly removed from within the tree or the production equipment may remain in the well bore and

the tree retrieved from the wellhead housing. This is achieved in a manner which is both simpler and easier than in current designs. The possibility of being able to drill through the tree without worry of damage e.g. to sealing surfaces can reduce both installation and drilling costs.

Further variants, combinations and permutations of the illustrated embodiments will be readily apparent. For example, the external cap of Figure 4 can be used in combination with the adapter of Figures. 1 - 3; the cap of Figure 4 can be internal instead of external and the Figures 1-3 annulus passage can use gallery seals or stabs as shown in Figure 8. Moreover, the Figure 8 annulus passage can extend vertically through the tubing hanger extension 130 to interface with the tree cap, similar to the arrangements shown in Figures 4 and 6, but with the tubing hanger extension replacing the service line housing 90 or tubular extension members 62, 63, 64, 65.

Claims:

1. A subsea wellhead completion system comprising:

a wellhead housing;

a christmas tree disposed above said wellhead housing and having an axial through bore;

connecting means for connecting said christmas tree to said wellhead housing;

said christmas tree including a first lateral production port for communicating said axial through bore with an external production line;

a tubing hanger installable in the wellhead through the axial through bore and having a production bore extending therethrough, said tubing hanger including a closure arrangement selectively operable to seal said production bore;

a removable cap which in use seals an upper end of the axial through bore so as to isolate a portion of the axial through bore and form a void in communication with the production port and the tubing hanger production bore.

2. A subsea wellhead completion system as defined in claim 1 in which the tubing hanger has at least one service bore extending therethrough, said service bore communicating with the well below the tubing hanger,

said tree and/or tree cap including at least one service port for communicating with an external service line;

an adapter extending into said axial through bore and including at least one service passage extending therethrough, a lower end of said service passage communicating with said service bore and an upper end of said passage communicating with said service port.

3. A subsea wellhead completion system according to claim 2, wherein said adapter is movable vertically relative to said tubing hanger and is removable from said upper internal bore when said cap is removed and when said closure arrangement closes said lower production bore, to enable said tree to be disconnected from said wellhead housing.

4. A subsea wellhead completion system according to claim 2 or 3, wherein said adapter is releasably locked in the tree.

5. A subsea wellhead completion system according to claim 2, 3 or 4, wherein said adapter is releasably locked to the tubing hanger.

6. A subsea wellhead completion system according to any of claims 2 - 5, wherein said adapter is releasably locked to a sub disposed between said wellhead and said tree, the sub having at least one lateral service port.

7. A subsea wellhead completion system according to any of claims 2 - 6, wherein said adapter extends in said upper internal bore above said lateral production port.

8. A subsea wellhead completion system according to any of claims 2 - 7, wherein said adapter comprises a tubular extension that mates in use with a receptacle in said tubing hanger.

9. A subsea wellhead completion system according to any of claims 2 - 8, wherein said adapter comprises a housing having bores for mating with receptacles in said tubing hanger, the housing having an arcuate cross-sectional configuration.

10. A subsea wellhead completion system comprising:

a wellhead housing;

a christmas tree disposed above said wellhead housing and having an axial through bore;

connecting means for connecting said christmas tree to said wellhead housing;

said christmas tree including a first lateral production port for communicating said axial through bore with an external production line;

a tubing hanger installable in the wellhead and having a production bore extending therethrough, said tubing hanger including a closure arrangement selectively operable to seal said production bore;

a removable cap which in use seals an upper end of the axial through bore;

the tubing hanger and production bore extending into the tree in use, for communication with the lateral production port.

11. A subsea wellhead completion system as defined in claim 10 in which the tubing hanger is installable in the wellhead through the axial through bore.

12. A subsea wellhead completion system as defined in claim 10 or 11 in which communication between the tubing hanger production bore and the lateral production port in the tree is via a movable seal stab.

13. A subsea wellhead completion system as defined in claim 10, 11 or 12 in which the tubing hanger has a vertical through bore, part of which forms part of the production bore.

14. A subsea wellhead completion system as defined in any of claims 10 - 13 in which the tubing hanger has at least one service passage extending therethrough, said service passage communicating with the well below the tubing hanger,
said tree and/or tree cap including at least one service port for communicating with an external service line;
said service passage extending into the tree in use, an upper end of said service passage communicating with said service port.

15. A subsea wellhead completion system according to any preceding claim, further including radially inner and outer casing hangers supported within said lower internal bore, said tubing hanger being supported on said radially inner casing hanger.

16. A subsea wellhead completion system according to any preceding claim, wherein the tree cap comprises a through bore and a closure arrangement selectively operable to seal the tree cap through bore.

17. A subsea wellhead completion system according to any preceding claim, comprising a movable plug installable in a profile in the tree cap and in a corresponding profile in the tubing hanger production bore.

18. A subsea wellhead completion system according to any preceding claim, wherein the christmas tree bore has a generally cylindrical interior wall, the tree cap being sealed to the christmas tree using sealing surfaces remote from the interior wall.

19. A method of servicing a subsea well comprising a subsea wellhead completion system as defined in any of claims 2 - 9, said method comprising the steps of:

A) setting a blowout preventer on an upper end of said christmas tree;

B) removing said adapter and said tubing hanger from said christmas tree together.

20. The method according to claim 19 further including, prior to step B, the step of closing said tubing hanger production bore.

21. The method according to claim 20 using a completion system according to claim 17 wherein the tubing hanger production bore is closed by moving the plug from the tree cap profile to the tubing hanger profile.

22. The method according to claim 21 further including, prior to step B and after moving the plug, the step of removing the cap from said tree.

23. A method of establishing a subsea well by means of a subsea completion as defined in any of claims 1 - 18, comprising the steps of:

a) drilling a hole in the sea bed;

b) insatalling said wellhead housing, including a surface casing extending downwardly therefrom into the hole;

c) connecting said tree to said wellhead housing;

d) setting a blowout preventer on an upper end of said tree; and

e) with the blowout preventer still installed,

i) further drilling and installing casing in the hole;

ii) landing said tubing hanger in said wellhead housing,

g) and then removing said blow out preventer.

24. A method according to claim 23 using a subsea wellhead as defined in any of claims 2-9 in which the adaptor is run together with the tubing hanger.

Amendments to the claims have been filed as follows

1. A subsea wellhead completion system comprising:
a wellhead housing;
a christmas tree disposed above said wellhead housing and having an axial through bore;
connecting means for connecting said christmas tree to said wellhead housing;
said christmas tree including a first lateral production port for communicating said axial through bore with an external production line;
a tubing hanger installable in the wellhead housing through the axial through bore and having a production bore extending therethrough, said tubing hanger including a closure arrangement selectively operable to seal said production bore; and
a removable cap which in use seals an upper end of the axial through bore so as to isolate a portion of the axial through bore and form a void in communication with the production port and the tubing hanger production bore.

2. A subsea wellhead completion system as defined in claim 1 in which the tubing hanger has at least one service bore extending therethrough, said service bore communicating with the well below the tubing hanger,
said tree and/or tree cap including at least one service port for communicating with an external service line;
an adapter extending into said axial through bore and including at least one service passage extending therethrough, a lower end of said service passage communicating with said service bore and an upper end of said passage communicating with said service port.

3. A subsea wellhead completion system according to claim 2, wherein when said cap is removed and when said closure arrangement closes said tubing hanger production bore, said adapter is movable vertically relative to said tubing hanger and is removable from said axial through bore to enable said tree to be disconnected from said wellhead housing.

4. A subsea wellhead completion system according to claim 2 or 3, wherein said adapter is releasably locked in the tree.

5. A subsea wellhead completion system according to claim 2, 3 or 4, wherein said adapter is releasably locked to the tubing hanger.

6. A subsea wellhead completion system according to any of claims 2 - 5, wherein said adapter is releasably locked to a sub disposed between said wellhead housing and said tree, the sub having at least one lateral service port.

7. A subsea wellhead completion system according to any of claims 2 - 6, wherein said adapter extends in said upper internal bore above said lateral production port.

8. A subsea wellhead completion system according to any of claims 2 - 7, wherein said adapter comprises a tubular extension that mates in use with a receptacle in said tubing hanger.

9. A subsea wellhead completion system according to any of claims 2 - 8, wherein said adapter comprises a housing having bores for mating with receptacles in said tubing hanger, the housing having an arcuate horizontal cross-sectional configuration.

10. A subsea wellhead completion system comprising:
a wellhead housing;
a christmas tree disposed above said wellhead housing and having an axial through bore;
connecting means for connecting said christmas tree to said wellhead housing;
said christmas tree including a first lateral production port for communicating said axial through bore with an external production line;
a tubing hanger installed in the wellhead housing and having a production bore extending therethrough, said tubing hanger including a closure arrangement selectively operable to seal said production bore;
a removable cap which in use seals an upper end of the axial through bore;
the tubing hanger and production bore extending into the tree in use, for communication with the lateral production port.

11. A subsea wellhead completion system as defined in claim 10 in which the tubing hanger is installable in the wellhead housing through the axial through bore.

12. A subsea wellhead completion system as defined in claim 10 or 11 in which communication between the tubing hanger production bore and the lateral production port in the tree is via a movable seal stab.

13. A subsea wellhead completion system as defined in claim 10, 11 or 12 in which the tubing hanger has a vertical through bore, part of which forms part of the production bore.

14. A subsea wellhead completion system as defined in any of claims 10 - 13 in which the tubing hanger has at least one service passage extending therethrough, said service passage communicating with the well below the tubing hanger,
said tree and/or tree cap including at least one service port for communicating with an external service line;
said service passage extending into the tree in use, an upper end of said service passage communicating with said service port.

15. A subsea wellhead completion system according to any preceding claim, further including radially inner and outer casing hangers supported within said wellhead housing, said tubing hanger being supported on said radially inner casing hanger.

16. A subsea wellhead completion system according to any preceding claim, wherein the tree cap comprises a through bore and a closure arrangement selectively operable to seal the tree cap through bore.

17. A subsea wellhead completion system according to any preceding claim, comprising a movable plug installable in a profile in the tree cap and in a corresponding profile in the tubing hanger production bore.

18. A subsea wellhead completion system according to any preceding claim, wherein the christmas tree bore has a generally cylindrical interior wall, the tree cap being sealed to the christmas tree using sealing surfaces remote from the interior wall.

19. A method of servicing a subsea well comprising a subsea wellhead completion system as defined in any of claims 2 - 9, said method comprising the steps of:

A) setting a blowout preventer on an upper end of said christmas tree;
B) removing said adapter and said tubing hanger from said christmas tree together.

20. The method according to claim 19 further including, prior to step B, the step of closing said tubing hanger production bore.

21. The method according to claim 20 using a completion system according to claim 17 wherein the tubing hanger production bore is closed by moving the plug from the tree cap profile to the tubing hanger profile.

22. The method according to claim 21 further including, prior to step B and after moving the plug, the step of removing the cap from said tree.

23. A method of establishing a subsea well by means of a subsea completion as defined in any of claims 1 - 18, comprising the steps of:

a) drilling a hole in the sea bed;

b) insatalling said wellhead housing, including a surface casing extending downwardly therefrom into the hole;

c) connecting said tree to said wellhead housing;

d) setting a blowout preventer on an upper end of said tree; and

e) with the blowout preventer still installed,

i) further drilling and installing casing in the hole;

ii) landing said tubing hanger in said wellhead housing,

g) and then removing said blow out preventer.

24. A method according to claim 23 using a subsea wellhead as defined in any of claims 2-9 in which the adaptor is run together with the tubing hanger.

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Claims searched: 1-24
Examiner: Alan Jones
Date of search: 10 April 2003

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X, Y	X: 1, 2, 7, 8, 10, 11, 13-16, 18, 23 Y: 12	US 5372199 A	(CEGIELSKI ET AL) see eg. fig 2A-C
Y	12	GB 2370296 A	(FMC CORP.) see whole doc.
A		EP 0719905 A1	(COOPER CAMERON CORP.)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[V]:

E1F

Worldwide search of patent documents classified in the following areas of the IPC[7]:

E21B

The following online and other databases have been used in the preparation of this search report :

Online: WPI, EPODOC, JAPIO